Riesche & Beeby

A Comparison of the Efficiencies Of a Two-Hinged & a Three-Hinged Steel Arch

Civil Engineering

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A COMPARISON OF THE EFFICIENCIES OF A TWO-HINGED AND A THREE-HINGED STEEL ARCH

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BY

ROBERT HERMAN RIESCHE
FRANK FAIRWELL BEEBY

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

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FRANK FAIRWELL BEEBY and ROBERT HERMAN RIESCHE

ENTITLED A COMPARISON OF THE EFFICIENCIES OF A TWO-HINGED AND A THREE-HINGED STEEL ARCH

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Civil Engineering

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The object of this thesis is to [illegible] the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] when acting as a [illegible], and [illegible] when acting as a [illegible] the same loading being used in both cases.

The beam used is that of the [illegible] [illegible] [illegible] [illegible] [illegible]

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The object of this thesis is to determine the relative weights of the main members of a steel roof-truss arch, first when acting as a three-hinged arch, and second when acting as a two-hinged arch, the same loading being used in both cases.

The arch used is that of the Baltimore Armory (Eng. Rec. Vol. 49 pp. 604), which was designed as a three-hinged arch. This arch has a span of 190 feet 3-3/4 inches, center to center of hinges, and a rise of 86 feet 6 inches above the finished floor line, the floor line being 1 foot 6 inches above the center of the end pins. The upper chord panel points are on the circumference of a circle whose radius is 111 feet 10 inches, the center being 17 feet 4 inches below the floor line. The lower chord panel points are on the circumference of a circle whose radius is 91 feet 10 inches, the center being 5 feet 4 inches below the floor line. The arches are spaced 25 feet 10 inches, center to center. The upper chord is divided into nineteen equal panels, each panel being 12 feet 8-15/16 inches long. The roof is designed for a wind load of 30 pounds per square foot of its vertical projection, and for a snow load varying from 2 to 30 pounds per square foot of horizontal projection of the upper six panels on each side of the center. The specifications used in this design were those given by Ketchum in his "Steel Mill Buildings", and are as follows:

Tensile Stresses

Shapes, main members, net sections .... 16,000 pounds per square inch.

Bars .... 16,000 pounds per square inch.

Compressive Stresses.

Shapes .... $S = 16,000 - 70\ l/r$ pounds per square inch.
Least allowable $l/r = 125$.
No metal less than 1/4 inch thick shall be used.

All stresses in both the two and the three-hinged arch are obtained graphically, and the stress and space diagrams are shown in Plate 1. From inspection, it was assured that a combination of the dead and wind load stresses would give a maximum deflection at the free end when the two-hinged arch was designed as a single truss. Therefore, the stresses resulting from this combination were used in both designs.

The design of the three-hinged arch was a simple theoretical design. The aim was to get the smallest section that would carry the given loads, little attention being paid to the practical considerations which might, in some cases, have required the use of larger members. (See Tables 1 and 2).

The design of the truss, treated as a two-hinged arch, was made according to the theory given by Ketchum in his "Steel Mill Buildings." The stresses used are given in Table 3. The formulae used are $\Delta = PUL/E$, $\Delta' = P'UL/E$, and $H = H'\frac{\Delta}{\Delta'}$, where

Δ is the horizontal deformation due to a horizontal thrust H';

H is the horizontal thrust required to keep the free end of the arch, when designed as a simple truss, from moving;

H' is a horizontal thrust, arbitrarily chosen, (in this case it is 20,000 pounds);

P is the unit stress in each member due to the loads;

P' is the unit stress in each member due to the horizontal thrust H';

U is the unit stress in a member due to a unit horizontal thrust applied at the free end of the simple truss;

L is the length of the member in inches;

E is the modulus of elasticity of structural steel (28000000).

The method of procedure in this case is as follows:-

The members were first designed and the deflections calculated (see Table 4), assuming the arch to act as a simple truss free to move at one end. Then, using the sections chosen in Table 4, the deflections, caused by a horizontal thrust of 20,000 pounds applied at the free end of the truss, were calculated (see Table 5). From the formula $H = H'\frac{\Delta}{\Delta'}$ it was found that the true horizontal thrust was 53,000 pounds, or 2.65 x 20,000 pounds. The stresses due to a horizontal thrust of 53,000 pounds were then combined with those caused by the given loads. The members were then redesigned using this combination of stresses, and the deformation computed. From the formula $H = H'\frac{\Delta}{\Delta'}$ it was seen that these must be an additional horizontal thrust of 13,300 pounds, making a total of 66,400 pounds or 3.315 x 20,000 pounds. In this manner, after four trials, the true horizontal thrust of 66,600 pounds was determined and the final design made (see Table 7). The total weight of the main members was then determined (see Table 8).

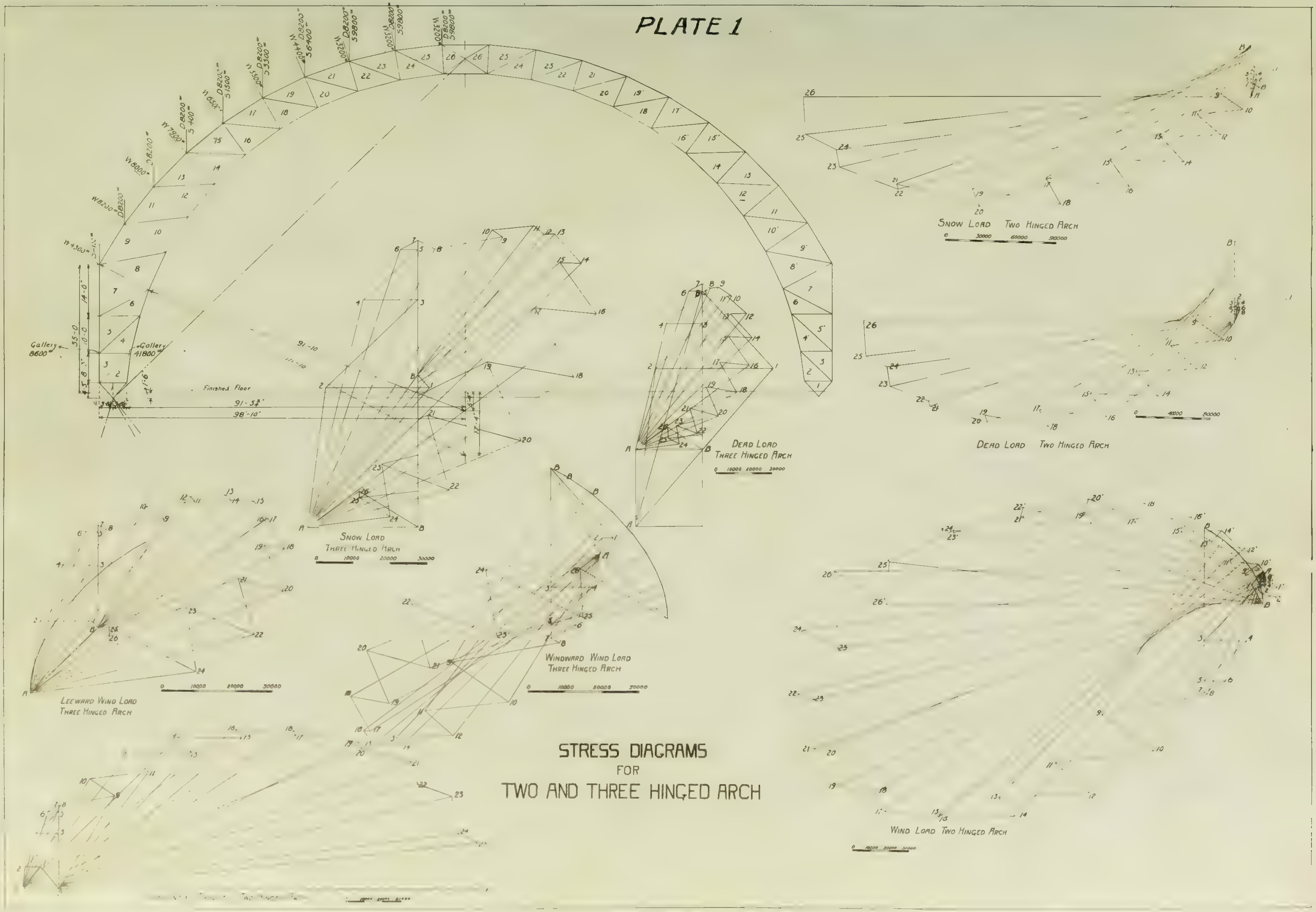
Conclusion.

The weight of the main members of this arch as here designed, treated both as a two-hinged and a three-hinged arch, is considerably below that of the arch as designed and erected at Baltimore. It is also less than that found by Mr. E. B. Jordan

in his thesis of 1908 where he designed for a combination of dead and wind load stresses.

When designed for dead and snow load stresses, the weight of the main member of the truss, treated as a two hinged arch, is 27,200 pounds, and treated as a three-hinged arch, 25,400 pounds. This gives an advantage of 1,800 pounds or, 7.1%, in favor of the three-hinged arch.

PLATE 1



STRESS DIAGRAMS
FOR
TWO AND THREE HINGED ARCH

TABLE 1 THREE HINGED ARCH STRESSES.

MEM.	Dead Load Stress	Snow Load Stress	Wind Load Stress	D.L.+S.L. Stress	D.L + Wind Stress	MAX. D.L+S.L.
A-1	+113100	+50100	+5800	+163200	+118900	+163200
A-1'	"	"	+25800	"	+138900	"
B-1	+57000	+4700	+25500	+61700	+82500	+61700
B-1'	"	"	-2300	"	+52300	"
1-2	-63300	-28000	-3000	-91300	-66300	-91300
1'-2'	"	"	-14200	"	-77500	"
A-2	+86000	+38000	+4400	+124000	+90400	+124000
A-2'	"		+19600	"	+105600	"
2-3	+35100	+34400	-19000	+69500	+16100	+69500
2'-3'	"	"	+22000	"	+57100	"
B-3	+18000	-20000	+32100	-2000	+50100	-2000
B-3'	"	"	-17000	"	+1000	"
3-4	-19500	-15000	+10100	-34500	-9400	-34500
3'-4'	"	"	-9800	"	-29300	"
A-4	+70000	+103300	-9200	+173300	+60800	+173300
A-4'	"	"	+36000	"	+106000	"
4-5	+26200	+20000	-15000	+46200	+11200	+46200
4'-5'	"	"	+13400	"	+39600	"
B-5	-8700	-34000	+42200	-42700	+33500	-42700
B-5'	"	"	-26000	"	-34700	"
5-6	-7200	-5000	+6900	-12200	-300	-12200
5'-6'	"	"	-3700	"	-10900	"
A-6	+90800	+79000	-20200	+169800	+70600	+169800
A-6'	"	"	+46200	"	+137000	"
6-7	+8000	+5300	-7800	+13300	+200	+13300
6'-7'	"	"	+4100	"	+12100	"
B-7	-11600	-36200	+46000	-47800	+34400	-47800
B-7'	"	"	-27800	"	-39400	"
7-8	+5000	+5100	+2500	+10100	+7500	+10100
7'-8'	"	"	"	"	"	"
A-8	+96000	+83000	-26400	+179000	+79600	+179000
A-8'	"	"	+49000	"	+145000	"
8-9	+4500	+18600	-29700	+23100	-25200	+23100
8'-9'	"	"	+16300	"	+20800	"
B-9	-16800	-43800	+59000	-60600	+42200	-60600

TABLE 1

MEM.	Dead Load Stress	Snow Load Stress	Wind Load Stress	D.L + S.L. Stress	D.L + W.L Stress	MAX. D.L. + S.L.
B-9'	-16800	-43800	-34600	-60600	-51400	-60600
9-10	+ 8500	- 3500	+19000	+ 5000	+27500	+ 5000
9'-10'	"	"	- 6100	"	+ 2400	"
A-10	+98000	+94600	-47000	+192600	+51000	+192600
A-10'	"	"	+59700	"	+157700	"
10-11	- 2500	+11200	-23000	+ 8700	-25500	+8700
10'-11'	"	"	-13500	"	-16000	"
B-11	-22000	-51000	+74000	- 73000	+52000	-73000
B-11'	"	"	-43200	"	-65200	"
11-12	+14000	+3800	+10300	+17800	+24300	+17800
11'-12'	"	"	- 2000	"	+12000	"
A-12	+95000	+101500	-63200	+196500	+31800	+196500
A-12'	"	"	+68800	"	+163800	"
B-13	-22000	-53000	+84800	-75000	+62800	-75000
B-13'	"	"	-50000	"	-72000	"
12-13	- 9000	+3000	-15700	- 6000	-24700	-6000
12'-13'	"	"	+10000	"	+1000	"
13-14	+17500	+10800	+ 2500	+20300	+20000	+20300
13'-14'	"	"	+2000	"	+19500	"
A-14	+87200	+102700	-74300	+189900	+ 2900	+189900
A-14'	"	"	+75600	"	+162800	"
B-15	-18700	-49000	+90400	-67700	+71700	-67700
B-15'	"	"	-54600	"	-73300	"
14-15	-12800	- 6000	- 7800	-18800	-20600	-18800
14'-15'	"	"	+6200	"	- 6600	"
15-16	+19000	+17000	-4700	+36000	+14300	+36000
15'-16'	"	"	+5800	"	+24800	"
A-16	+76800	+97000	-80000	+173800	- 3200	+173800
A-16'	"	"	+79800	"	+156600	"
B-17	-11000	-37200	+89000	-48200	+78000	-48200
B-17'	"	"	-54800	"	-65800	"
16-17	-16000	-17000	+2000	-33000	-14000	-33000
16'-17'	"	"	+500	"	-15500	"
17-18	+19000	+21500	-10800	+40500	+8200	+40500
17'-18'	"	"	+9300	"	+28300	"

TABLE 1

MEM.	Dead Load Stress	Snow Load Stress	Wind Load Stress	D.L + S.L Stress	D.L + W.L Stress	MAX. D.L.+S.L.
A-18	+62500	+82300	−78000	+144800	+15500	+144800
A-18''	"	"	+79500	"	+142000	"
B-19	− 2200	−20700	+80900	−22900	+78700	−22900
B-19'	"	"	−50500	"	−52700	"
18-19	−17000	−24000	+10700	−41000	+6300	−41000
18'-19'	"	"	−5600	"	−22600	"
19-20	+17000	+23000	−15700	+40000	+ 1300	+40000
19'-20'	"	"	+13500	"	+80500	"
A-20	+48300	+62000	−68500	+110300	+20200	+110300
A-20'	"		+74300	"	+122600	"
B-21	+ 7000	− 3000	+66800	+4000	+73800	+4000
B-21'	"	"	−40500	"	−33500	"
20-21	−16000	−26000	+18000	−42000	+ 2000	−42000
20'-21'	"	"	−12800	"	−28800	"
21-22	+14300	+21000	−18000	+35300	− 3700	+35300
21'-22'	"	"	+16000	"	+30300	"
A-22	+34300	+39600	−52900	+73900	−18600	+73900
A-22'	"	"	+63000	"	+97300	"
B-23	+14300	+10200	+46800	+24500	+61100	+24500
B-23'	"	"	−24000	"	−9700	"
22-23	−12200	−19800	+25000	−32000	+12800	−32000
22'-23'	"	"	−20800	"	−33000	"
23-24	+10000	+14600	−18200	+24600	− 8200	+24600
23'-24'	"	"	+17600	"	+27600	"
A-24	+24000	+22500	−31200	+46500	−7200	+46500
A-24'	"	"	+45000	"	+21000	"
B-25	+18300	+16000	+23000	+34300	+41300	+34300
B-25'	"	"	− 1500	"	+16800	"
24-25	− 6700	−10000	+28400	−16700	+21700	−16700
24'-25'	"	"	−27500	"	−34200	"
25-26	− 6000	− 2000	−13500	− 8000	−19500	− 8000
25'-26'	"	"	+ 2600	"	− 3400	"
A-26	+21200	+17000	− 6800	+38200	+14400	+38200
A-26'	"	"	+26500	"	+47700	"
B-26	+22000	+35000	+27500	+57000	+49500	+57000

− 3500

TABLE 2 THREE-HINGED ARCH

Member	Length		Shapes		Weight	
Number.	Inch.	Feet.	Size and	Number	Per. Foot	Total.
A-26	84	7.0	2 [s 6" x 10.5#	@ 10.5	21.0	147.0
A-1	68	5.66	4 ∠s 5"×3"×$\frac{7}{16}$"	@ 11.3	45.2	256.0
B-1	"	"	2 ∠s 5"×3"×$\frac{5}{16}$"	@ 8.2	16.4	92.8
1-2	88	7.34	2 ∠s 5"×4"×$\frac{5}{8}$"	@ 11.0	22.0	161.8
A-2	100	8.33	2 [s 7"-17.25#	@ 17.25	34.5	287.0
2-3	182	15.18	2 ∠s 5"×3"×$\frac{5}{8}$"	@ 15.7	31.4	476.5
B-3	99	8.25	2 ∠s 2"×2"×$\frac{1}{4}$"	@ 3.2	6.4	52.8
3-4	101	8.42	2 ∠s 2"×2"×$\frac{7}{16}$"	@ 5.3	10.6	89.3
A-4	102	8.50	2 [s 10"-25#	@ 25.0	50.0	425.0
4-5	176	14.67	2 ∠s 4$\frac{1}{2}$"×3"×$\frac{1}{2}$"	@ 11.9	23.8	349.0
B-5	120	10.0	2 ∠s 2$\frac{1}{4}$"×2$\frac{1}{4}$"×$\frac{7}{16}$"	@ 6.1	12.2	122.0
5-6	130	10.84	2 ∠s 2"×2"×$\frac{1}{4}$"	@ 3.2	6.4	69.3
A-6	88	7.34	2 [s 10"-20#	@ 20.0	40.0	293.6
6-7	179	14.90	2 ∠s 4$\frac{1}{2}$"×3"×$\frac{5}{16}$"	@ 7.7	15.4	229.3
B-7	168	14.00	2 ∠s 2$\frac{1}{4}$"×2$\frac{1}{4}$×$\frac{1}{2}$"	@ 6.8	13.6	190.5
7-8	178	14.83	2 ∠s 4$\frac{1}{2}$"×3"×$\frac{5}{16}$"	@ 7.7	15.4	228.5
A-8	135	11.25	2 [s 10"-25#	@ 25.0	50.0	560.3
8-9	218	18.18	2 ∠s 6"×3$\frac{1}{2}$"×$\frac{3}{8}$"	@ 11.7	23.4	425.0
B-9	153	12.76	2 ∠s 2$\frac{3}{4}$"×2$\frac{3}{4}$"×$\frac{1}{2}$"	@ 8.5	17.0	217.0
9-10	164	13.68	2 ∠s 4$\frac{1}{2}$"×3"×$\frac{5}{16}$"	@ 7.7	15.4	210.5
A-10	134	11.18	2 [s 10"-25#	@ 25.0	50.0	558.0
10-11	208	17.35	2 ∠s 4$\frac{1}{2}$"×3"×$\frac{5}{16}$"	@ 7.7	15.4	267.0
B-11	153	12.75	2 ∠s 3"×3"×$\frac{9}{16}$"	@ 10.4	20.8	265.2

TABLE 2 THREE-HINGED ARCH.

Member Number	Length		Shapes		Weight	
	Inch.	Feet	Sizes	Number.	Per.Foot	Total.
11-12	150	12.50	2 Ls 4"x3"x5/16"	@ 7.2	14.4	180.0
A-12	138	11.50	2 [s 10"-30#	@ 30.0	60.0	690.0
B-13	153	12.75	2 Ls 3"x3"x9/16"	@ 10.4	20.8	265.2
12-13	196	16.35	2 Ls 2"x2"x1/4"	@ 3.2	6.4	104.6
13-14	138	11.50	2 Ls 3½"x2½"x1/4"	@ 4.9	9.8	112.5
14-A	"	"	2 [s 10"-25#	@ 25.0	50.0	567.0
B-15	153	12.75	2 Ls 3"x3"x½"	@ 9.4	18.8	240.0
14-15	192	16.00	2 Ls 2"x2"x1/4"	@ 3.2	6.4	102.5
15-16	126	10.50	2 Ls 3½"x2½"x7/16"	@ 8.3	16.6	174.2
A-16	140	11.68	2 [s 10"-25#	@ 25.0	50.0	583.0
B-17	153	12.75	2 Ls 2¼"x2¼"x½"	@ 6.8	13.6	173.6
16-17	186	15.50	2 Ls 2"x2"x7/16"	@ 5.3	10.6	164.3
17-18	116	9.76	2 Ls 3½"x2"x9/16"	@ 9.0	18.0	175.9
A-18	142	11.82	2 [s 10"-20#	@ 20.0	40.0	473.0
B-19	153	12.75	2 Ls 2"x2"x1/4"	@ 3.2	6.4	81.6
18-19	182	15.16	2 Ls 2¼"x2¼"x7/16"	@ 6.1	12.2	185.0
19-20	108	9.00	2 Ls 3½"x2"x9/16"	@ 9.0	18.0	162.0
A-20	141	11.76	2 [s 9"-15#	@ 15.0	30.0	352.0
B-21	153	12.75	2 Ls 4"x3"x5/16"	@ 7.2	14.4	184.0
20-21	180	15.00	2 Ls 2¼"x2¼"x7/16"	@ 6.1	12.2	183.0
21-22	102	8.50	2 Ls 3"x2½"x7/16"	@ 7.6	15.2	129.1
A-22	141	11.76	2 [s 7"-12.25#	@ 12.25	24.5	288.0

TABLE 2 THREE-HINGED ARCH

Member.	Length.		Shapes		Weight	
Number.	Inch.	Feet.	Sizes and	Number	Per. Foot.	Total.
B-23	153	12.75	2 Ls 4"x3"x$\frac{5}{16}$"	@ 7.2	14.4	184.0
22-23	176	14.67	2 Ls 2"x2"x$\frac{7}{16}$"	@ 5.3	10.6	155.1
23-24	98	8.16	2 Ls 3"x2"x$\frac{5}{16}$"	@ 5.0	10.0	81.6
A-24	142	11.82	2 [s 6"-10.5#	@ 10.5	21.0	248.0
B-25	153	12.75	2 Ls 4"x3"x$\frac{3}{8}$"	@ 8.5	17.0	217.0
24-25	176	14.67	2 Ls 2"x2"x$\frac{1}{4}$"	@ 3.2	6.4	93.8
25-26	95	7.91	2 Ls 2x2x$\frac{1}{4}$"	@ 3.2	6.4	50.6
B-26	84	7.0	2 [s 6"-10.5#	@ 10.5	21.0	147.0
					Total	12721.0
			Total Weight both sides	25442.0#		

TABLE 3 TWO-HINGED ARCH

Member	D.L. Stress	S.L. Stress	W.L. Stress	H.T. Stress	D.L.+S.L. Stress	D.L.+W.L. Stress
A-1	+84 500	+27000	-9600	+15 500	+111 500	+74 900
A-1'	+84 500	+27 000	+11 600	+15 500		+96100
A-2	+71 800	+21 200	-7 500	+11 800	+93 000	+64 300
A-2'	+71 800	+21 200	+9 000	+11 800		+80 800
A-4	+15 000	+18 800	-39 200	+30800	+33 800	-24 400
A-4'	+15 000	+18 800	+8000	+30800		+23 000
A-6	+11 500	+14 900	-62800	+44 200	+26 400	-51 300
A-6'	+11 500	+14900	+6 000	+44 200		+17500
A-8	+6 500	+10 000	-73 300	+49 000	+16 500	-66800
A-8'	+6 500	+10 000	+4 000	+49 000		+10 500
A-10	-31 000	-9 000	-11400	+70 000	-40 000	-145 000
A-10'	-31 000	-9 000	-4 000	+70 000		-35 000
A-12	-80 000	-36 200	-152 700	+93 000	-116 200	-232 700
A-12'	-80 000	-36 200	-15 800	+93 000		-95 800
A-14	-139 500	-72 000	-189 000	+118 200	-211 500	-328 500
A-14'	-139 500	-72 000	-31 500	+118 200		-171 000
A-16	-208 000	-118 300	-220 800	+144 700	-226 300	-428 000
A-16'	-208 000	-118 300	-51 500	+144 700		-259 500
A-18	-279 500	-172 000	-244 200	+171 000	-451 500	-523 700
A-18'	-279 500	-172 000	-76 800	+171 000		-356 300
A-20	-355 500	-231 400	-259 200	+199 700	-586 900	-614 700
A-20'	-355 500	-231 400	-106 100	+199 700		-461 500
A-22	-428 700	-288 500	-262 900	+222 700	-717 200	-691 600
A-22'	-428 700	-288 500	-138 800	+222 700		-567 500
A-24	-485 000	-330 000	-255 000	+239 300	-815 000	-740 000
A-24'	-485 000	-330 000	-174 000	+239 300		-659 000
A-26	-517 300	-355 000	-237 000	+249 000	-872 300	-754 000
B-1	+84 500	+27 000	+40 000	-15 500	+111 500	+124 500
B-1'	+84 500	+27 000	+12 000	-15 500		+96 500
B-3	+73 200	+23 000	+61 000	-30 000	+96 200	+134 200
B-3'	+73 200	+23 000	+10 500	-30 000		+83 700
B-5	+76 500	+27 200	+82 500	-41 800	+103 700	+159 000
B-5'	+76 500	+27 200	+12 300	-41 800		+88 800
B-7	+78 600	+29 900	+88 800	-44 900	+108 500	+167 400
B-7'	+78 600	+29 900	+13 400	-44 900		+92 000

TABLE 3

Member	D.L. Stress	S.L. Stress	W.L. Stress	H.T. Stress	D.L.+ S.L. Stress	D.L.+ W.L. Stress
B-9	+95000	+435000	+115500	-58500	+118500	+210500
B-9'	+95000	+43500	+19200	-58500		+114200
B-11	+136000	+675000	+151300	-79800	+203500	+287300
B-11'	+136000	+67500	+29500	-79800		+165500
B-13	+184000	+100000	+185600	-103500	+284000	+369600
B-13'	+184000	+100000	+43700	-103500		+227700
B-15	+242700	+142400	+216200	-128800	+385100	+458900
B-15'	+242700	+142400	+62200	-128800		+304900
B-17	+345000	+191700	+239500	-153500	+536700	+584500
B-17'	+345000	+191700	+85800	-153500		+430800
B-19	+245400	+367500	+255000	-181600	+612900	+622500
B-19'	+245400	+367500	+113000	-181600		+480500
B-21	+297200	+439000	+259600	-203800	+736200	+698600
B-21'	+297200	+439000	+144200	-203800		+583200
B-23	+334000	+489400	+252800	-219700	+823400	+742200
B-23'	+334000	+489400	+177000	-219700		+666400
B-25	+356200	+517200	+236700	-229000	+873400	+753900
B-25'	+356200	+517200	+209400	-229000		+726600
B-26	+355000	+517300	+209000	-229000	+872300	+726300
1-2	-14700	-45800	+5400	-8500	-60500	-40400
2-3	-12500	-4000	-43900	+26000	-16500	-56400
3-4	+3500	+4300	+23100	-12800	+7800	-26600
4-5	-4800	-59000	-31500	+17500	-10700	-36300
5-6	+3800	+4900	+11800	-5700	+8700	+15600
6-7	-4300	-5600	-13400	+6400	-9900	-17700
7-8	+3800	+48000	+1700	+800	+8600	+5500
8-9	-53400	-27300	-58700	+30200	-80700	-112100
9-10	+40200	+21400	+34300	-16400	+61600	+74500
10-11	-67600	-36800	-54300	+32100	-104400	-121900
11-12	+43700	+24800	+24500	-14200	+68900	+68200
12-13	-78800	-47200	-49500	+34400	-126000	-128300
13-14	+42000	+27000	+14000	-6100	+69000	+56000
14-15	-88000	-58800	-42000	+34900	-146800	-130000
15-16	+35700	+26400	+800	-6000	+62100	+36500
16-17	-88600	-66300	-30600	+33200	-154900	-119200

TABLE 3

Member	D.L. Stress	S.L. Stress	W.L. Stress	H.T. Stress	D.L.+S.L. Stress	D.L.+S.L. Stress
17-18	+25200	+22800	-11500	-2800	+48000	+13700
18-19	-93000	-71000	-19700	+36000	-164100	-112700
19-20	+13400	+17400	-20500	+3800	+30800	-7.100
20-21	-87000	-68000	-6000	+28000	-155000	-93000
21-22	-4500	+3000	-30000	+12600	-1500	-34500
22-23	-65000	-49000	+7600	+19700	-114500	-57900
23-24	-28500	-15400	-37000	+20300	-43900	-65500
24-25	-36000	-29500	+19600	+11300	-65500	-16400
25-26	-43500	-29000	-42000	+25000	-72500	-85500
1'-2'	-45800	-14700	-6500	-8500	-60500	-52300
2'-3'	-12500	-4000	-1700	+26000	-16500	-14200
3'-4'	+3500	+4300	+1900	-12800	+7800	+5400
4'-5'	-4800	-5900	-2800	+17500	-10700	-7600
5'-6'	+3800	+4900	+2000	-5700	-8700	-5800
6'-7'	-4300	-5600	-2400	+6400	-9900	-6700
7'-8'	+3800	+4800	+2000	+800	+8600	+5800
8'-9'	-53400	-27300	-11800	+30200	-80700	-65200
9'-10'	+40200	+21400	+9400	-16400	+61600	+49600
10'-11'	-67600	-36800	-16000	+32100	-104400	-83600
11'-12'	+43700	+24800	+10800	-14200	+86500	+54500
12'-13'	-78800	-47200	-20600	+34400	-12600	-99400
13'-14'	+42000	+27000	+12000	-6100	+69000	+54000
14'-15'	-88000	-58800	-25700	+34900	-146800	-113700
15'-16'	+35700	+26400	+12000	-6000	+62100	+47700
16'-17'	-88600	-66300	-31500	+33200	-154900	-120100
17'-18'	+25200	+22800	+11600	-2800	+48000	+63800
18'-19'	-93000	-71700	-35300	+36000	-164100	-128300
19'-20'	+13400	+17400	+9200	+3800	+30800	+22600
20'-21'	-87000	-68000	-39000	+28000	-155000	-126000
21'-22'	-4500	+3000	+5200	+12600	-1500	+700
22'-23'	-65500	-49000	-40900	+19700	-11450	+106400
23'-24'	-28500	-15400	+1000	+20300	-43900	-27500
24'-25'	-36000	-29500	-39400	+11300	-65500	-75400
25'-26'	-43500	-29000	-23400	+25000	-72500	-66900
26-26'	00	00	+33400	00	00	+33400

TABLE 4

Member	Area Sq. In.	Length in Ft.	Stress in Pounds	Unit Stress P in Pounds	$\frac{PL}{E}$	U	$\frac{PUL}{E}$
A-1	10.24	5.67	+ 111500	10880	0.0268	+ 0.775	- 0.02075
A-2	6.7	8.33	+ 93000	13880	0.0496	+ 0.590	- 0.02925
A-4	3.9	8.50	+ 33800	8670	0.0316	+ 1.540	- 0.04870
A-6	3.9	7.33	+ 26400	6770	0.0225	+ 2.210	- 0.04975
A-8	3.9	11.25	+ 16500	4230	0.0204	+ 2.450	- 0.05000
A-10	3.9	11.17	- 40000	10250	0.0514	+ 3.500	+ 0.17000
A-12	7.78	11.50	- 116200	14940	0.0736	+ 4.650	+ 0.34200
A-14	17.64	11.50	- 211500	11940	0.0611	+ 5.900	+ 0.36000
A-16	17.64	11.67	- 226300	12820	0.0641	+ 7.200	+ 0.46150
A-18	19.80	11.83	- 451500	22880	0.1156	+ 8.550	+ 0.95400
A-20	19.80	11.75	- 586900	29600	0.1490	+ 9.950	+ 1.48200
A-22	19.80	11.75	- 717200	36200	0.1825	+ 11.100	+ 2.02500
A-24	19.80	11.83	- 815000	41200	0.2090	+ 11.940	+ 2.49500
A-26	19.80	11.83	- 872300	43000	0.2181	+ 12.44	+ 2.71500
B-1	7.78	5.67	+ 111500	14320	0.0346	- 0.775	+ 0.02684
B-3	6.70	8.25	+ 96200	14350	0.0396	- 1.500	+ 0.05945
B-5	7.78	10.00	+ 103700	13200	0.0566	- 2.050	+ 0.11600
B-7	8.92	14.00	+ 108500	12170	0.0731	- 2.245	+ 0.17900
B-9	8.92	12.75	+ 118500	13280	0.0726	- 3.420	+ 0.24800
B-11	12.60	12.75	+ 203500	19250	0.1010	- 3.990	+ 0.40450
B-13	19.80	12.75	+ 284000	14850	0.0812	- 5.175	+ 0.41950
B-15	19.80	12.75	+ 385100	19450	0.1063	- 6.440	+ 0.68500

TABLE 4

Member	Area Sq. In.	Length in Ft.	Stress in Pounds	Unit Stress P in Pounds	$\frac{PL}{E}$	U	$\frac{PUL}{E}$
B-17	19.80	12.75	+536 700	27 050	0.1480	- 7.675	+1.13600
B-19	19.80	12.75	+612 900	30 900	0.1690	- 9.080	+1.53400
B-21	19.80	12.75	+736 200	37 200	0.1875	-10.190	+1.91100
B-23	19.80	12.75	+823 400	41 500	0.2268	-10.985	+2.49100
B-25	19.80	12.75	+873 400	44 000	0.2408	- 11.450	+2.7600
B-26	19.80	12.75	+872 300	44 000	0.2408	- 11.450	+2.7600
1-2	3.86	7.33	- 60 500	15 680	0.0492	- 0.425	- 0.0209
2-3	1.06	15.17	- 16 500	15 600	0.1015	+ 1.300	+ 0.1320
3-4	1.19	8.42	+ 7 800	6 550	0.0236	- 0.640	+ 0.0151
4-5	1.06	14.67	- 10 700	10 100	0.0492	+ 0.875	+ 0.0431
5-6	2.09	10.83	+ 8 700	4 150	0.0193	- 0.485	+ 0.0094
6-7	1.06	14.92	- 9 900	9 330	0.0597	+ 0.320	+ 0.0191
7-8	3.61	14.67	+ 8 600	2 380	0.0149	+ 0.040	- 0.0060
8-9	5.00	18.17	- 80 700	16 140	0.1258	+ 1.510	+ 0.1900
9-10	4.11	13.67	+ 61 600	15 000	0.0882	- 0.820	+ 0.0728
10-11	6.62	17.33	- 104 400	15 800	0.1174	+ 1.605	+ 0.1886
11-12	6.46	12.50	+ 68 500	10 650	0.0569	- 0.710	+ 0.0403
12-13	7.62	16.33	- 126 000	17 450	0.1222	+ 1.720	+ 0.2100
13-14	6.46	11.50	+ 69 000	10 680	0.0577	- 0.305	+ 0.0176
14-15	8.36	16.00	- 146 800	17 450	0.1003	+ 1.745	+ 0.1746
15-16	6.46	10.50	+ 62 100	9 420	0.0424	- 0.300	+ 0.1272
16-17	8.36	15.50	- 154 900	18 500	0.1230	+ 1.660	+ 0.2043

TABLE 4

Member	Area Sq. In.	Length in Ft.	Stress Pounds	Unit Stress P in lbs.	$\frac{PL}{E}$	U	$\frac{PUL}{E}$
17-18	4.80	9.63	+ 48000	10000	0.0413	- 0.140	+ 0.0058
18-19	8.36	15.17	- 164100	19600	0.1273	+ 1.800	+ 0.2286
19-20	3.75	9.00	+ 30800	8200	0.0316	+ 0.190	- 0.0060
20-21	8.36	15.00	- 155000	18550	0.1191	+ 1.400	+ 0.1669
21-22	1.06	8.50	- 1500	1410	0.0514	+ 0.630	+ 0.0324
22-23	6.50	14.67	- 114500	17600	0.1260	+ 0.985	+ 0.1241
23-24	3.25	8.17	- 43900	13500	0.0423	+ 1.015	+ 0.0429
24-25	3.75	14.67	- 65500	17450	0.1098	+ 0.565	+ 0.6200
25-26	4.61	7.92	- 72500	15710	0.0417	+ 1.250	+ 0.0522
26-26′		14.50					+

$$\Delta = \Sigma \frac{PUL}{E} = +50.5386$$

TABLE 5

Member	Area Sq. In.	Length in Ft.	Stress due to H.T.=20000#	Unit Stress P in Lbs.	$\frac{PL}{E}$	U	$\frac{PUL}{E}$
A-1	10.24	5.67	+ 15500	1510	0.0037	+ 0.775	- 0.00256
A-2	6.7	8.33	+ 11800	1760	0.0063	+ 0.590	- 0.00372
A-4	3.9	8.50	+ 30800	7900	0.0288	+ 1.540	- 0.04315
A-6	3.9	7.33	+ 44200	11340	0.0365	+ 2.210	- 0.07465
A-8	3.9	11.25	+ 49000	12560	0.0606	+ 2.450	- 0.14835
A-10	3.9	11.17	+ 70000	17950	0.0860	+ 3.500	- 0.30100
A-12	7.78	11.50	+ 93000	11950	0.0590	+ 4.650	- 0.27450
A-14	17.64	11.50	+ 118200	6700	0.0275	+ 5.900	- 0.16220
A-16	17.64	11.67	+ 144700	8200	0.0411	+ 7.200	- 0.39550
A-18	19.80	11.75	+ 171000	8640	0.0437	+ 8.550	- 0.37356
A-20	19.80	11.75	+ 199700	10080	0.0508	+ 9.950	- 0.50500
A-22	19.80	11.83	+ 222700	11240	0.0567	+ 11.100	- 0.63000
A-24	19.80	11.83	+ 239300	12080	0.0612	+ 11.940	- 0.73150
A-26	19.80	11.83	+ 249000	12570	0.0637	+ 12.440	- 0.79300
B-1	7.78	5.67	- 15500	1990	0.0048	- 0.775	- 0.00372
B-3	6.70	8.25	- 30000	4480	0.0158	- 1.500	- 0.02370
B-5	7.78	10.00	- 41800	5380	0.0230	- 2.050	- 0.04715
B-7	8.92	14.00	- 44900	5030	0.0302	- 2.245	- 0.06800
B-9	8.92	12.75	- 58500	6560	0.0358	- 3.420	- 0.12450
B-11	12.06	12.75	- 79800	6720	0.0367	- 3.990	- 0.14640
B-13	19.80	12.75	- 103500	5200	0.0284	- 5.175	- 0.14600
B-15	19.80	12.75	- 128800	6500	0.0355	- 6.440	- 0.22880

TABLE 5

Member	Area Sq. In.	Length in Ft.	Stress due to H.T.=20000#	Unit Stress P in Lbs.	$\frac{PL}{E}$	U	$\frac{PUL}{E}$
B-17	19.80	12.75	-153 500	7 750	0.0424	-7.675	-0.32580
B-19	19.80	12.75	-181 600	9 170	0.0501	-9.080	-0.4550
B-21	19.80	12.75	-203800	10 280	0.0562	-10.190	-0.5730
B-23	19.80	12.75	-219 700	11 100	0.0607	-10.985	-0.6665
B-25	19.80	12.75	-229 000	11 550	0.0632	-11.450	-0.7240
B-26	19.80	12.75	-229 000	11 550	0.0632	-11.450	-0.7240
1-2	3.86	7.33	- 8 500	2 200	0.0069	- 0.425	- 0.0029
2-3	1.06	15.17	+26 000	24 600	0.1600	+ 1.300	- 0.2080
3-4	1.19	8.42	- 12 800	10 750	0.0323	- 0.640	- 0.0207
4-5	1.06	14.67	+ 17 500	16 500	0.1038	+ 0.875	- 0.0908
5-6	2.09	10.83	- 5 700	2 730	0.0127	- 0.485	- 0.0062
6-7	1.06	14.92	+ 6400	6040	0.0386	+ 0.320	- 0.0123
7-8	3.61	14.67	+ 800	220	0.0014	+ 0.040	- 0.0006
8-9	5.00	18.17	+ 30200	6 040	0.0470	+ 1.510	- 0.0710
9-10	4.11	13.67	- 16 400	3990	0.0234	- 0.820	- 0.0192
10-11	6.62	17.33	+ 32 100	4850	0.0360	+ 1.605	- 0.0578
11-12	6.46	12.50	- 14200	2220	0.0118	- 0.710	- 0.0084
12-13	7.22	16.33	+ 34400	4770	0.0334	+ 1.720	- 0.0575
13-14	6.46	11.50	- 6 100	950	0.0047	- 0.305	- 0.0014
14-15	8.36	16.00	+ 34900	4180	0.0286	+ 1.745	- 0.0498
15-16	6.46	10.50	- 6000	930	0.0041	- 0.300	- 0.0012
16-17	8.36	15.50	+ 33 200	3980	0.0264	+ 1.660	- 0.0438

TABLE 5

Member	Area in Sq. In.	Length in Ft.	Stress due to H.T.=20000#	Unit Stress P' in Lbs.	$\frac{PL}{E}$	U	$\frac{PUL}{E}$
17-18	4.80	9.63	- 2 800	580	0.0024	- 0.140	- 0.0003
18-19	8.36	15.17	+36000	4 310	0.0280	+ 1.800	- 0.0504
19-20	3.75	9.00	+ 3 800	1 010	0.0039	+ 0.190	- 0.0007
20-21	8.36	15.00	+28000	3 350	0.0216	+ 1.400	- 0.0303
21-22	1.06	8.50	+ 12 600	11 890	0.0433	+ 0.630	- 0.0273
22-23	6.50	14.67	+ 19 700	3 320	0.0209	+ 0.985	- 0.0206
23-24	3.25	8.17	+ 20 300	6 240	0.0218	+ 1.015	- 0.0221
24-25	3.75	14.67	+ 11 300	3 012	0.0189	+ 0.565	- 0.0107
25-26	4.61	7.92	+ 25 000	5 430	0.0184	+ 1.250	- 0.0230
26-26'		14.50					

$$\Delta' = \Sigma \frac{P'UL}{E} = -19.0686$$

$$H : 20000 = \Delta : \Delta'$$

$$H = \frac{20000 \times 50.5386}{19.0686} = 53\,000$$

$$53\,000 = 2.65 \times 20000$$

TABLE 6

Member	D.L.+ S.L. Pounds	2.65 x H.T. Pounds	Σ 2+3 Pounds	Area Sq. In.	Unit Stress P	Length Ft.	$\frac{P.L.}{E}$	U	$\frac{PUL}{E}$
A-1	+ 111 500	+ 41 100	+ 152 600	12.0	12 700	5.67	0.0308	+ 0.775	- 0.0233
A-2	+ 93 000	+ 31 300	+ 124 300	8.92	13 930	8.33	0.0498	+ 0.590	- 0.0292
A-4	+ 33 800	+ 81 700	+ 115 500	8.92	12 950	8.50	0.0472	+ 1.540	- 0.0728
A-6	+ 26 400	+ 117 000	+ 143 400	11.76	12 180	7.33	0.0383	+ 2.210	- 0.0775
A-8	+ 16 500	+ 129 800	+ 146 300	11.76	12 440	11.25	0.0600	+ 2.450	- 0.1470
A-10	- 40 000	+ 185 500	+ 145 500	11.76	12 380	11.17	0.0594	+ 3.500	- 0.2080
A-12	- 116 200	+ 246 500	+ 130 300	11.76	11 080	11.50	0.0547	+ 4.650	- 0.2540
A-14	- 211 500	+ 313 200	+ 101 700	7.78	12 900	11.50	0.0637	+ 5.900	- 0.3760
A-16	- 226 300	+ 383 500	+ 157 200	11.76	13 380	11.67	0.0688	+ 7.200	- 0.4950
A-18	- 451 500	+ 453 000	+ 1 500	2.38	630	11.83	0.0032	+ 8.550	- 0.2735
A-20	- 586 900	+ 529 500	- 57 400	3.90	14 710	11.75	0.0742	+ 9.950	+ 0.7380
A-22	- 717 200	+ 564 000	- 153 200	11.76	13 020	11.75	0.0657	+ 11.100	+ 0.7295
A-24	- 815 000	+ 634 500	- 180 500	12.60	12 730	11.83	0.0647	+ 11.940	+ 0.7730
A-26	- 872 300	+ 660 000	- 192 300	14.70	12 080	11.83	0.0614	+ 12.440	+ 0.7640
B-1	+ 111 500	+ 41 150	+ 70 350	5.70	12 330	5.67	0.0300	- 0.775	+ 0.0232
B-3	+ 96 200	+ 79 500	+ 16 700	2.38	7020	8.25	0.0285	- 1.550	+ 0.0428
B-5	+ 103 700	- 108 600	- 4 900	2.38	2 060	10.00	0.0088	- 2.050	- 0.0184
B-7	+ 108 500	- 119 000	- 1 500	2.38	630	14.00	0.0038	- 2.245	- 0.0081
B-9	+ 118 500	- 155 000	- 36 500	2.38	15 320	12.75	0.0829	- 3.420	- 0.2835
B-11	+ 203 500	- 213 700	- 10 200	2.38	4 280	12.75	0.0234	- 3.990	- 0.0934
B-13	+ 284 000	- 274 300	+ 9 700	3.10	3 120	12.75	0.0171	- 5.175	+ 0.0885
B-15	+ 385 100	- 341 500	+ 43 600	4.76	9 180	12.75	0.0502	- 6.440	+ 0.3230

TABLE 6

Member	D.L.+S.L. Pounds	2.65x H.T. Pounds	Σ 2+3 Pounds	Area Sq.In.	Unit Stress P	Length Ft.	$\frac{PL}{E}$	U	$\frac{PUL}{E}$
B-17	+536 700	-407 000	+129 700	11.76	11 020	12.75	0.0234	- 7.675	-0.0934
B-19	+612 000	-481 500	+131 400	11.76	11 180	12.75	0.0171	-9.080	+0.0885
B-21	+736 200	-540 000	+196 200	14.70	13 370	12.75	0.0502	-10.190	+0.3230
B-23	+823 400	-582 500	+240 900	19.80	12 180	12.75	0.0603	-10.985	+0.4630
B-25	+872 400	-607 000	+266 400	19.80	13 460	12.75	0.0612	-11.450	+0.5555
B-26	+872 300	-607 000	+265 300	19.80	13 380	12.75	0.0731	-11.450	+0.7450
1-2	- 60 500	- 22 600	+ 83 100	7.50	11 080	7.33	0.0666	-0.425	+0.7320
2-3	- 16 500	+ 68 950	+ 52 450	5.75	9120	15.17	0.0736	+ 1.300	+0.8430
3-4	+ 7 800	- 33 920	- 26 120	2.30	11 340	8.42	0.0410	- 0.640	+0.8380
4-5	-10 700	+41 400	+ 30 700	4.18	7 350	14.67	0.0460	+ 0.875	-0.0148
5-6	+ 8 700	- 15 100	- 6 400	1.06	6 040	10.83	0.0281	- 0.485	-0.0772
6-7	- 9 900	+ 16 950	+ 7 050	3.61	1 950	14.92	0.0125	+0.320	-0.0263
7-8	+ 8 600	+ 2 120	+10 720	3.61	2 970	14.67	0.0187	+0.040	-0.0404
8-9	-80 700	+80 100	- 600	1.06	560	18.17	0.0044	+1.510	-0.0136
9-10	+61 600	-43 480	+18 120	3.61	5 020	13.67	0.0294	-0.820	+0.0233
10-11	-104 400	+85 100	-19 300	1.78	10 840	17.33	0.0807	+ 1.605	+ 0.1294
11-12	+ 68 500	-37 600	+30 900	3.61	8 560	12.50	0.0459	- 0.710	+ 0.0326
12-13	-126 000	+91 200	-34 800	2.86	12 170	16.33	0.0853	+ 1.720	+ 0.1468
13-14	+ 69 000	-16 150	+52 850	5.06	10 450	11.50	0.0515	- 0.305	+ 0.0157
14-15	-146 800	+92 500	-54 300	4.61	11 780	16.00	0.0809	+ 1.745	+ 0.1412
15-16	+ 62 100	- 15 890	+46 200	4.36	10 600	10.50	0.0477	- 0.300	+0.0143
16-17	-154 900	+ 88 000	-66 900	5.23	12 780	15.50	0.0850	+ 1.660	+0.1410

TABLE 6

Member	D.L.+S.L. Pounds	2.65× H.T. Pounds	Σ 2+3 Pounds	Area Sq. In.	Unit Stress P	Length Ft.	$\frac{PL}{E}$	U	$\frac{PUL}{E}$
17-18	+ 48 000	- 7 420	+ 40 580	4.18	9 720	9.63	0.0401	- 0.140	+ 0.0056
18-19	- 164 100	+ 95 500	- 68 600	5.72	11 980	15.17	0.0780	+ 1.800	+ 0.1404
19-20	+ 30 800	+ 10 070	+ 40 870	4.18	9 780	9.00	0.0378	+ 0.190	- 0.0072
20-21	- 155 000	+ 74 200	- 80 800	7.75	10 420	15.00	0.0671	+ 1.400	+ 0.0940
21-22	- 1 500	+ 33 400	+ 31 900	3.31	9 640	8.50	0.0352	+ 0.630	- 0.0222
22-23	- 114 500	+ 52 200	- 62 300	5.75	10 820	14.67	0.0675	+ 0.985	+ 0.0665
23-24	- 43 900	+ 53 800	+ 9 900	1.44	6 870	8.17	0.0241	+ 1.015	- 0.0245
24-25	- 65 500	+ 29 600	- 35 900	3.53	10 170	14.67	0.0641	+ 0.565	+ 0.0362
25-26	- 72 500	+ 66 250	- 6 250	1.31	4 770	7.92	0.0378	+ 1.250	+ 0.0472

$$\Delta = \Sigma \frac{PUL}{E} = +12.71$$

$$H = \frac{20000 \times 12.71}{19.07} = 13\,300$$

$$53000 + 13\,300 = 66\,300$$

$$66\,300 = 3.315 \times 20000$$

TABLE 7

Member	D.L.+S.L. Pounds	3.33 × H.T. Pounds	Σ 2+3 Pounds	Area Sq. In.	Unit Stress P	Length Ft.	$\frac{PL}{E}$	U	$\frac{PUL}{E}$
A-1	+111 500	+51 600	+163 100	11.76	+13 890	5.67	0.0337	+0.775	-0.0261
A-2	+93 000	+39 300	+132 300	11.76	+11 320	8.33	0.0404	+0.590	-0.0238
A-4	+33 800	+102 000	+135 800	11.76	+11 540	8.50	0.0420	+1.540	-0.0648
A-6	+26 400	+147 000	+173 400	12.06	+14 380	7.33	0.0452	+2.210	-0.1000
A-8	+16 500	+163 000	+179 500	14.70	+12 200	11.25	0.0590	+2.450	-0.1444
A-10	-40 000	+233 000	+193 000	14.70	+13 120	11.17	0.0628	+3.500	-0.2200
A-12	-116 200	+310 000	+193 800	14.70	+13 180	11.50	0.0650	+4.650	-0.3020
A-14	-211 500	+394 000	+182 500	14.70	+12 830	11.50	0.0633	+5.900	-0.3735
A-16	-226 300	+482 000	+255 700	19.80	+12 900	11.67	0.0649	+7.200	-0.4640
A-18	-451 500	+570 000	+118 500	11.76	+10 080	11.83	0.0511	+8.550	-0.4375
A-20	-586 900	+663 000	+76 100	7.22	+8 700	11.75	0.0438	+9.950	-0.4365
A-22	-717 200	+741 000	+23 800	4.18	+5 700	11.75	0.0287	+11.100	-0.3186
A-24	-815 000	+797 000	-18 000	2.38	-7 560	11.83	0.0383	+11.940	+0.4580
A-26	-872 300	+830 000	-42 300	4.22	-10 010	11.83	0.0508	+12.440	+0.6350
B-1	+111 500	-51 600	+59 900	4.98	+12 020	5.67	0.0292	-0.775	+0.0227
B-3	+96 200	-100 000	-3 800	1.88	-2 020	8.25	0.0071	-1.500	-0.0107
B-5	+103 700	-139 000	-35 300	2.88	-12 250	10.00	0.0525	-2.050	-0.1770
B-7	+108 500	-153 000	-44 500	3.56	-12 500	14.00	0.0750	-2.245	-0.1686
B-9	+118 500	-195 000	-77 000	5.72	-13 460	12.75	0.0736	-3.420	-0.2618
B-11	+203 500	-265 500	-62 000	4.60	-13 480	12.75	0.0737	-3.990	-0.2940
B-13	+284 000	-343 000	-59 000	4.60	-12 830	12.75	0.0702	-5.175	-0.3633
B-15	+385 100	-426 000	-40 900	3.56	-11 500	12.75	0.0629	-6.440	-0.4050

TABLE 7

Member	D.L.+S.L. Pounds	3.33 × H.T. Pounds	Σ 2+3 Pounds	Area Sq. In.	Unit Stress P	Length Ft.	$\frac{P.L}{E}$	U	$\frac{PUL}{E}$
B-17	+ 536 700	- 510 000	+ 26 700	4.18	6 400	12.75	+ 0.0350	- 7.675	+ 0.2682
B-19	+ 612 900	- 605 000	+ 7 900	4.18	1890	12.75	+ 0.0103	- 9.080	+ 0.0936
B-21	+ 736 200	- 676 000	+ 60200	6.86	8 780	12.75	+ 0.0480	- 10.190	+ 0.5270
B-23	+ 823 400	- 732000	+ 91 400	9.50	9 140	12.75	+ 0.0525	- 10.985	+ 0.5760
B-25	+ 873 400	- 763 000	+ 110400	11.76	9 400	12.75	+ 0.0513	- 11.450	+ 0.5880
B-26	+ 872 300	- 763000	+ 109 300	11.76	9 300	12.75	+ 0.0508	- 11.450	+ 0.5825
1-2	- 60 500	- 28 300	- 88 800	6.48	13 700	7.33	- 0.0430	- 0.425	- 0.0183
2-3	- 16 500	+ 86 700	+ 70 200	8.38	8 380	15.17	+ 0.0545	+ 1.300	- 0.0708
3-4	+ 7800	- 42 600	- 34 800	2.88	12 080	8.42	- 0.0436	- 0.640	- 0.0278
4-5	- 10 700	+ 58300	+ 47600	6.10	7 800	14.67	+ 0.0491	+ 0.875	- 0.0429
5-6	+ 8 700	- 19 000	- 10 300	2.14	4810	10.830	- 0.0224	- 0.485	- 0.0108
6-7	- 9 900	+ 21 400	+ 11 500	4.82	2 380	14.92	+ 0.0153	+ 0.320	- 0.0049
7-8	+ 8 600	+ 2 650	+ 11 250	4.82	2 330	14.67	+ 0.0147	+ 0.040	- 0.0059
8-9	- 80 700	+ 100 700	+ 20000	6.86	2 915	18.17	+ 0.0227	+ 1.510	- 0.0343
9-10	+ 61 600	+ 54700	+ 6 900	4.82	1 430	13.67	+ 0.0084	- 0.820	+ 0.0069
10-11	- 104400	+ 106 700	+ 2 300	6.86	329	17.33	+ 0.0024	+ 1.605	- 0.0039
11-12	+ 68 500	- 47 300	+ 21 200	4.18	5070	12.50	+ 0.0272	- 0.710	+ 0.0193
12-13	- 126 000	+ 114 500	- 13 500	2.38	5 680	16.33	- 0.0396	+ 1.720	+ 0.0682
13-14	+ 69000	- 20 300	+ 48 700	4.82	10 100	11.50	+ 0.0498	- 0.305	+ 0.0152
14-15	- 146 800	+ 116 200	- 30 600	2.38	14880	16.00	- 0.1020	+ 1.745	+ 0.1780
15-16	+ 62 100	- 20 000	+ 42 100	4.82	8 730	10.50	+ 0.0213	- 0.300	+ 0.0061
16-17	- 154 900	+ 110 700	- 44200	3.26	13 550	15.50	- 0.0901	+ 1.660	+ 0.1496

TABLE 7

Member	D.L.+S.L. Pounds	3.33 × H.T. Pounds	Σ 2+3 Pounds	Area Sq. In	Unit Stress P	Length Ft.	$\frac{PL}{E}$	U	$\frac{PUL}{E}$
17-18	+ 48 000	- 9 300	+ 38 700	4.18	9260	9.63	0.0382	- 0.140	+ 0.0053
18-19	- 164 100	+ 120 000	- 44 100	3.26	13 520	15.17	0.0880	+ 1.800	+ 0.1582
19-20	+ 30 800	+ 12 600	+ 43 400	4.18	10 380	9.00	0.0400	+ 0.190	- 0.0076
20-21	- 155 000	+ 93 200	- 61 800	4.60	13 420	15.00	0.0865	+ 1.400	+ 0.1210
21-22	- 1 500	+ 41 900	+ 40 400	4.18	9 670	8.50	0.0352	+ 0.630	- 0.0222
22-23	- 114 500	+ 60 700	- 53 800	4.22	12 740	14.67	0.0802	+ 0.985	+ 0.0790
23-24	- 43 900	+ 67 600	+ 23 700	2.88	8 230	8.17	0.0288	+ 1.015	- 0.0292
24-25	- 65 500	+ 37 600	- 27 900	2.38	11 700	14.67	0.0737	+ 0.565	+ 0.0416
25-26	- 72 500	+ 83 300	+ 10 800	2.64	4 090	7.92	0.0139	+ 1.250	- 0.0174

$$\Delta = \Sigma \frac{PUL}{E} = 0.57$$

Which is close enough for our purpose.

TABLE 8

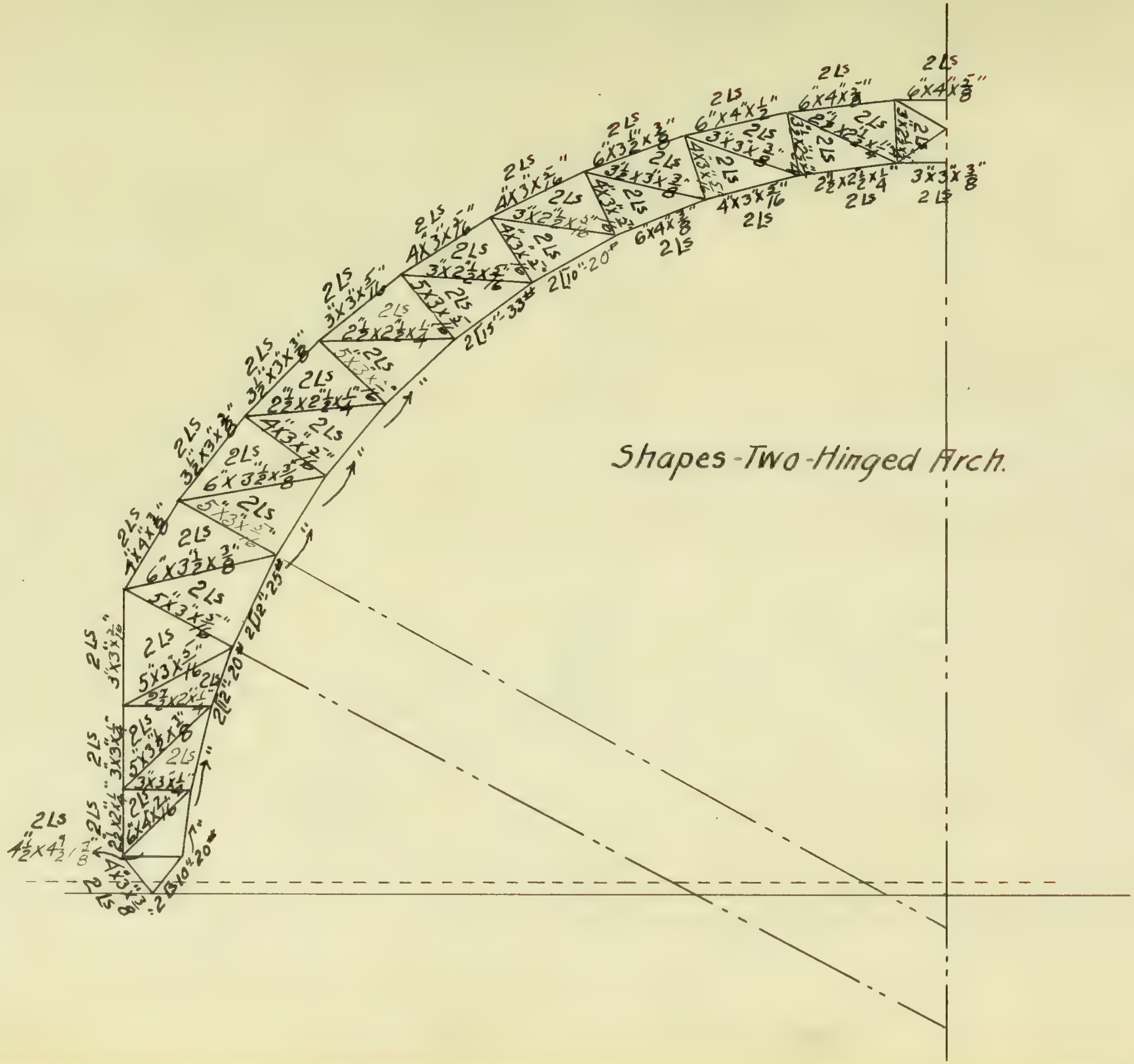
Member	Section	Length Ft.	Weight per Foot	Weight
A-1	2 10"-20# [s	5.67	40.00	226.8
A-2	2 10"-20# [s	8.33	40.00	332.0
A-4	2 10"-20# [s	8.50	40.00	340.0
A-6	2 12"-20.5# [s	7.33	41.00	300.0
A-8	2 12"-25# [s	11.25	50.00	562.0
A-10	2 12"-25# [s	11.17	50.00	557.0
A-12	2 12"-25# [s	11.50	50.00	575.0
A-14	2 12"-25# [s	11.50	50.00	575.0
A-16	2 15"-33# [s	11.67	66.00	770.0
A-18	2 10"-20# [s	11.83	40.00	473.0
A-20	2 6"x4"x3/8" Ls	11.75	24.60	289.0
A-22	2 4"x3"x5/16" Ls	11.75	14.40	169.2
A-24	2 2½"x2½"x¼" Ls	11.83	8.20	97.0
A-26	2 3"x3"x3/8" Ls	11.83	14.40	170.5
B-1	2 4"x3"x3/8" Ls	5.67	17.00	96.4
B-3	2 2½"x2"x¼" Ls	8.25	7.40	61.6
B-5	2 3"x3"x¼" Ls	10.00	9.80	98.0
B-7	2 3"x3"x5/16" Ls	14.00	12.20	171.0
B-9	2 4"x4"x3/8" Ls	12.75	19.60	250.0
B-11	2 3½"x3"x3/8" Ls	12.75	15.80	201.5
B-13	2 3½"x3"x3/8" Ls	12.75	15.80	201.5
B-15	2 3"x3"x5/16" Ls	12.75	12.20	155.5
B-17	2 4"x3"x5/16" Ls	12.75	14.40	183.5
B-19	2 4"x3"x5/16" Ls	12.75	14.40	183.5
B-21	2 6"x3½"x3/8" Ls	12.75	23.40	298.5
B-23	2 6"x4"x½" Ls	12.75	32.40	413.0
B-25	2 6"x4"x5/8" Ls	12.75	40.00	510.0
B-26	2 6"x4"x5/8" Ls	12.75	40.00	510.0
1-2	2 4½"x4½"x3/8" Ls	7.33	22.00	161.4
2-3	2 6"x4"x7/16" Ls	15.17	28.60	434.0
3-4	2 3"x3"x¼" Ls	8.42	9.80	82.5
4-5	2 5"x3½"x3/8" Ls	14.67	20.80	305.0
5-6	2 2½"x2"x¼" Ls	10.83	7.40	80.2
6-7	2 5"x3"x5/16" Ls	14.92	16.40	245.0
7-8	2 5"x3"x5/16" Ls	14.67	16.40	240.5

TABLE 8

Member	Section		Length Ft.	Weight per Foot	Weight
8-9	2	$6'' \times 3\frac{1}{2}'' \times \frac{3}{8}''$ Ls	18.17	23.40	425.0
9-10	2	$5'' \times 3'' \times \frac{5}{8}''$ Ls	13.67	16.40	224.0
10-11	2	$6'' \times 3\frac{1}{2}'' \times \frac{3}{8}''$ Ls	17.33	23.40	402.0
11-12	2	$4'' \times 3'' \times \frac{5}{16}''$ Ls	12.50	14.40	180.0
12-13	2	$2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{1}{4}''$ Ls	16.33	8.20	137.0
13-14	2	$5'' \times 3'' \times \frac{5}{16}''$ Ls	11.50	16.40	188.7
14-15	2	$2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{1}{4}''$ Ls	16.00	8.20	131.3
15-16	2	$5 \times 3 \times \frac{5}{16}''$ Ls	10.50	16.40	172.0
16-17	2	$3 \times 2\frac{1}{2} \times \frac{5}{16}$ Ls	15.50	11.20	173.6
17-18	2	$4'' \times 3'' \times \frac{5}{16}''$ Ls	9.63	14.40	138.7
18-19	2	$3'' \times 2\frac{1}{2}'' \times \frac{5}{16}''$ Ls	15.17	11.20	170.0
19-20	2	$4'' \times 3'' \times \frac{5}{16}''$ Ls	9.00	14.40	129.7
20-21	2	$3\frac{1}{2}'' \times 3'' \times \frac{3}{8}''$ Ls	15.00	15.80	237.0
21-22	2	$4'' \times 3'' \times \frac{5}{16}''$ Ls	8.50	14.40	122.5
22-23	2	$3'' \times 3'' \times \frac{3}{8}''$ Ls	14.67	12.20	179.0
23-24	2	$3\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{3}{8}''$ Ls	8.17	9.80	80.1
24-25	2	$2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{1}{4}''$ Ls	14.67	8.20	120.2
25-26	2	$3'' \times 2\frac{1}{2}'' \times \frac{1}{4}''$ Ls	7.92	9.00	71.3

Total Weight = 27200#

PLATE 2



Shapes-Two-Hinged Arch.

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